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The 1978–79 Purse-seine Skipjack Fishery in New Zealand Waters

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Setting the net from the purse seiner *Finisterre*.

Introduction

Since successful purse-seine surveys of New Zealand's skipjack (*Katsuwonus pelamis* Linnaeus, 1758) resource were carried out in 1974 and 1975 (Hinds 1974, Eggleston 1976), there has been a rapidly developing summer fishery for this species. Landings have risen from 5000 t in 1975–76 (1976 season) to almost 9000 t in 1978–79 (1979 season). Each season the Ministry of Agriculture and Fisheries (MAF) has monitored catch-per-effort of the commercial fleet fishing skipjack and related this to environmental parameters, skipjack biology, and fluctuations in size of the skipjack resource. The results of observations on earlier seasons were presented to the fishing industry and others at conferences in 1976 (Clement 1976, Habib 1976, Vooren 1976) and 1977 (Clement 1978, Eggleston and Paul 1978, Habib 1978a, Richardson 1978). Results of observations on the 1977–78 (1978) season were presented briefly in Habib (1978b) and in detail in Habib, Clement, and Fisher (in press). This publication presents information on the 1979 purse-seine skipjack fishery in New Zealand.

Materials and methods

Vessels

These were *Apollo* (1558 gross tonnes, 79 m overall length, 2000 t carrying capacity); *Zapata Discoverer* (1499 t, 69 m, 1650 t); *Voyager* (1472 t, 73 m, 1600 t); *Frontier* (1163 t, 67 m, 1135 t); *Finisterre* (1063 t, 62 m, 1150 t); *Island Princess* (1274 t, 66 m, 1250 t); *Jeanette C* (1091 t, 54 m, 813 t); *Janet D* (498 t, 35 m, 330 t); *Waihola* (as for *Janet D*); *San Benito* (248 t, 33 m, 120 t); *Marine Countess* (135 t, 27 m, 130 t); and *Lindberg* (159 t, 23 m, 90 t).

The first four vessels fished under charter to New Zealand Pelagic Fisheries Development Company (1976) Limited (NZPFDC) with *Finisterre*, the company-owned vessel. *Island Princess* and *Jeanette C* fished with licences which were issued to Van Camp Sea Food Company of California by the New Zealand Government under the Territorial Sea and Exclusive Economic Zone Act 1977.

Apollo, Zapata Discoverer, and *Island Princess*, which operated in the eastern Pacific Ocean tuna fishery outside the New Zealand season, travelled to New Zealand during December-January for the skipjack season. A further NZPFDC vessel *Michelangelo* sank en route from American Samoa to New Zealand. *Frontier*, which also joined the fishery from the eastern Pacific, was on her maiden voyage.

Voyager and *Jeanette C* left fishing grounds near Papua New Guinea and Palau to fish in New Zealand.

The remaining vessels, which were operated by other New Zealand companies, joined the New Zealand fishery from other New Zealand pelagic fisheries.

Gear

The vessels' nets ranged from 640 to 1682 m (2100 to 5518 ft) in length and 64 to 263 m (210 to 863 ft) in depth.

Observer programme

As in previous seasons, the Fisheries Divisions of MAF placed observers aboard the purse-seine vessels to record:

1. Vessel activity, subdivided into time and place searching and fishing, travelling, at anchor or in port carrying out repairs or survey requirements, discharging fish, taking stores, sheltering from poor weather, or taking time off.
2. Vessel fishing activity with location, date, time, depth, size, and success of sets.

Fig. 1: Set positions and quantities (t) of skipjack caught by area in the 1979 purse-seine skipjack fishery in New Zealand.

3. Weather and sea conditions.
4. Location and size of surface schools of skipjack and other pelagic fishes.
5. Lengths of skipjack and other species in the catches.
6. Reproductive state, food contents, and details of blood samples from skipjack.

Skipjack fork lengths were measured to the whole centimetre below the actual length in samples of 50–300 fish from all catches while observers were aboard the vessels. For studies on reproduction and feeding, 5–20 fish were dissected from occasional catches. The developmental stage of the gonads was judged by use of criteria described by Orange (1961) and Raju (1964). Stomach contents were either identified *in situ* or preserved in formalin for later identification ashore.

Ministry of Agriculture and Fisheries logs were also kept by observers and pilots in "spotter" aircraft flying in support of the skipjack fishery. Sightings of numbers and sizes of schools were recorded with notes on the date, time of day, locality, weather, and sea state. Most observations were made from commercial fish-spotting flights, supplemented by observations from wider-ranging MAF aerial surveys. Schools of skipjack were located and identified and school sizes estimated by use of criteria outlined by Bell (1976). These tasks were carried out by spotters with specialised training and considerable experience gained over several years of assisting pelagic fishing vessels (for discussion of these requirements see Squire 1972).

Hydrology

Sea surface temperatures were available from three sources: observers recorded temperatures from the purse-seine vessels by use of insulated bottles; an infrared thermometer (described in Robertson 1975) in one of the spotter aircraft recorded temperatures; and, as in 1977 (Eggleston and Paul 1978) and 1978 (Habib, Clement, and Fisher in press), MAF received sea surface temperature charts for the New Zealand region from the National Oceanic and Atmospheric Administration of the United States Department of Commerce. The manner in which the satellites measured the temperatures and the limitations on these data are discussed in Eggleston and Paul (1978).

An associated study of hydrology, in which water temperature, salinity, dissolved oxygen, and water clarity profiles across the continental shelf and slope were measured and plankton was collected, was conducted on the fishing ground between The Aldermen Islands and Cape Brett (see Fig. 1). The aim was to describe the physical characteristics of the main skipjack fishing ground in an attempt to understand the relationships between the environment and the skipjack resource. The results of this study will be presented in a separate publication.

Abundance

Two measures of abundance are used in this publication, apparent and real abundance.

Apparent abundance is defined by Marr (1951) as ". . . abundance as affected by availability, or the absolute number of fish accessible to a fishery." In this publication apparent abundance refers to the quantity of fish which was apparent at the surface each half-day and which was accessible to the purse-seine fleet on each half-day. It should, however, be appreciated that in adding together such amounts, fish which were quantified on one half-day probably often contributed to subsequent half-day totals. Therefore the total of all half-day measures of apparent abundance does not represent the quantity which could have been taken in the fishery and is to some extent an overestimate.

However, moderating this overestimate are other factors which caused the measures of apparent abundance on each half-day to be underestimated. These factors are the cursory nature of much sightings effort, the inadequate sightings effort in all skipjack fishing areas at some time during the season, and the movement of schools through the different levels of the sea during the day, which would have resulted in some proportion of the skipjack resource passing through the New Zealand region unsighted.

Real abundance refers to estimates of the absolute quantity of skipjack which passed through New Zealand waters. The means by which these estimates were obtained is discussed on page 26.

"Bodies" of skipjack

Much of the following discussion centres on the concept of a "body" of fish. In this publication, this refers to a close-knit group of schools of skipjack that could be seen (through aerial and shipboard observations) to be moving through the New Zealand area as a unit.

Tagging

In February-March 1979 the South Pacific Commission conducted a skipjack survey and assessment programme in New Zealand waters (Kearney and Hallier 1979). During the programme 11 614 skipjack were tagged and released from the Commission's pole and line vessel *Hatsutori Maru*. Some 945 of these fish

were recaptured shortly after along the north-east coast of the North Island, mostly by the purse seiners fishing the resource.

The tagging and recapture data, which will form the basis of publications by the South Pacific Commission, have undergone preliminary analyses at Fisheries Research Division. The results of these analyses are used in this publication to verify movements of bodies of skipjack as established through aerial and shipboard observations.

Comparisons with other seasons

In publications referred to above, comparisons were made with other seasons to give additional meaning to the bare statistics describing any one season. In this publication, such comparisons are kept to a minimum.

Definitions of effort

In the following analyses, a **season-day** is defined as any day that a purse seiner spent in activity related to the skipjack fishery. This includes days spent searching and fishing, travelling, in port, at anchor or at sea drifting, and days taken off.

Days fished are days on which a net was set or searching activity occurred with the aim of setting.

A **set** is defined as any time a net was released into the water to entrap a skipjack school and then retrieved; and sets were **successful** if at least 1 t of skipjack was caught, even if this represented only part of a school.

Areas

The fishery is discussed in terms of areas (Fig. 1, Table 1). These are areas A, Reef Point to North Cape; B, North Cape to Cavalli Islands; C, Cavalli Islands to Shoe Island (mainly east and north of Great Barrier Island); D, Bay of Plenty; E, East Cape to Hawke Bay; F, Hawke Bay to Cook Strait; G, Kaikoura Coast; H, west coast South Island; I, Kahurangi Point to New Plymouth; J, New Plymouth to Kaipara Harbour; K, Kaipara Harbour to Reef Point; and L, off shore north-east Northland. Areas F, G, H, and I are not, or are only partly, shown in Fig. 1, as no sets for skipjack were made in those areas.

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o)

				Area											
	Day			A	B	C	D	E	F	G	H	I	J	K	L
Nov	20	a.m.	e	+	+							+			
		p.m.	e		+	+	+								
	21		e			+ x	+ x					+			
			e			+ x	+ x					+			
	22		e			x	+ x					+			
			e			+ x	+ x								
	23		e			+ x	+								
			e			+ x	+								
	24						+					+			
							+					+			
	25											+			
	26						+					+			
							+					+			
	27						+					+			
			e		+	+	+					+			
	28		e	+	+			+					+	+	
												+	+		
	29						+	+	+			+			
							+	+				+			
	30						+					+			
							+								

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

			Area											
	Day		A	B	C	D	E	F	G	H	I	J	K	L
Dec	1	a.m.				+					+			
		p.m.				+					+			
	2					+								
						+					+			
	3					+					+			
						+								
	4					+					+			
						+								
	5		e		x	+					+			
			e		x	+								
	6					+					+			
						+								
	7					+								
						+								
	8					+								
						+								
	9					+					+			
						+								
	10					+					+			
						+					+			
	11					+					+			
						o					+			
	12					+					+			
						+					+			
	13					+					+			
						+					+			
	14					+					+			
						+					+o			
	15										+			
	16										+			
	17										+			
	18										+			
	19					+					+			
	20										+			
	21													
	22													
	23		e		+	+	+				+			
			e	+	+	+	+							
	24		e			x					+			
			e			x								
	25										+			
	26		e			x					+			
			e			x								
	27		e			+ x					+			
						+o	+							
	28					o					+			
						o								
	29		e			x	+				+			
			e			x	+				o			
	30					ox					+			
						o					o			
	31		e		+	+o	+				+			
			e	+	+	+o	+							

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

	Day			Area A	B	C	D	E	F	G	H	I	J	K	L
Jan	1	a.m.				o						+			
		p.m.			o	o									
	2					o						+o			
						o						o			
	3					o	+					+o			
						o	+					o			
	4		e	+	+	+ x	+					+o			
			e		+	+ x	+					+o			
	5		e			x	+					+	+		
			e		+	+ x						+	+		
	6		e			x						+			
			e			x									
	7					ox						+			
						ox									
	8					ox	+					+			
			e			x	+								
	9		e			x						+			
			e			+ x	+	+							
	10		e			+ x	+					+			x
			e		+	+ x	+								x
	11		e			+ x	+					+			+ x
			e			+ x	+								+ x
	12		e			+ x									+ x
			e			+ x									+ x
	13		e			+ x						+			+ x
			e			+ x									x
	14		e			+ x									x
			e			+ x	+					+			x
	15		e			+ x	+					+			
			e			+ x									
	16		e	+	+	+ x	+					+			
			e			+ x							+	+	
	17					+ox									
					o	o									
	18					o	o								
						+o	+o								
	19				o	ox	o								
					o	ox	+o								
	20					+ox	+								
			e			+ x	+	+							
	21		e			+ x	+ x								
			e			+ x	x						+		
	22		e			+ x	+ x								
			e			+ x	+ x								
	23		e			+ x	+ x	+				+	+		
			e			+ x	+ x	+	+		+	+			
	24					+ox	+ x								
					+	+ox	+ x								
	25		e		+	+ x	+ x								
			e			x	+ x								
	26		e			x	+ x								
			e			x	+ x								
	27		e			x	+ox						x		
			e			x	+ x						x		
	28		e			x	+ox						o		
						ox	+o						o		
	29		e			x	+ox						o		
			e			x	+o						o		
	30		e		+ x	+ x	+								
			e		+ x	x	+ x								
	31			+	+ x	+o	+ x								
			e	+	+ x	+ x	+ x								

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

				Area										
	Day			A	B	C	D	E	F	G	H	I	J	K	L
Feb	1	a.m.	e		+o	+o	+ x					+	x		
		p.m.	e	+	+o	o	+ x						+ x	+	
	2		e		o		+ x						x		
			e	+	+o	+	+ x				+	+	+ x	+	
	3		e		o		+ x						x		
			e		o		+ x						x		
	4				o	o	o						o		
					o	o	o					o	o		
	5				o		o						o		
			e		o	+	o						o		
	6		e	+	+	+	+ x						x		
			e		+	+ x	+ x						x		
	7		e		+ x	+ x	+ x						x		
			e		+ x	+ x	+ x						x		
	8		e		+ x	+ x	+ x					+			
			e		+ x	+ox	+ x					+		x	
	9		e		+ x	+ x	+ x	+							
			e		+ x	+ x	+ x								
	10		e	+	+ x	+	+ x								
			e	+	+ x	+	+ x								
	11		e		+ x		+ x								
			e		+ x		+ x						x		
	12		e		+ x	+	+ x						o		
			e		+ x	+	+o						o		
	13		e		+ox	+	+ x								
			e		+o	+	+	+							
	14		e		+ox	o									
					o	o									
	15		e		+ox	o	+ x								
			e		ox	o	+ x								
	16				ox	o	o								
					+o	+o	+o								
	17				o	o	o						o	o	
					o	o	o						o		
	18				ox	o	o						o		
					ox		o						x		
	19		e		x		+						ox		
			e		+ x	+	+o	x					+ox		
	20		e	+	+ x		+	+o					o		
			e	o	+ x	+	+	+o					ox		
	21		e		+ x	+		+ x					x		
			e		x			+ x					x		
	22		e					+ x					ox		
			e		o			+ x					ox		
	23		e				+	+o					x	x	
			e		+	+	+	o					ox		
	24		e		+	+o	+	o					o		
			e	+	+	+o	+	o					+ox		
	25		e		+	+ x		+ x					x		
			e			+o		+ x					+ x		
	26		e		x	+	+	+ x					x		
			e		+ x	+		+ x					x		
	27		e		+ x	+	+	+ x							x
			e		+ox	+ x	+	+ x							
	28		e		+ x	+ x	+	+o					o		
			e			+ox	+	+o					o		

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

	Day			Area A	B	C	D	E	F	G	H	I	J	K	L
Mar	1	a.m.	e		+ x	+ x		o					o		
		p.m.	e		+ x	+ x	+	+o						o	
	2		e		x	+ x		+ x					o		
			e		x	+ x		+ x					+		
	3		e		+	+ x	+ x	+ x							
			e		+	+ x	+ x	+							
	4		e		+	+ x	+ x	+							
			e			+ x	+ x	+							
	5		e			+ x	+ x	+							
			e			+ x	+ x	+							
	6		e			+ x	+ x	+							
			e			+ x	+ x	+							
	7		e			+ x	+ x	+							
			e			x	+ x	+							
	8		e			+ox	+ x						+		
			e			o	+ x						+		
	9		e			o	+ox								
						o	o								
	10					o	o								
						o	o								
	11						o								
						ox	o								
	12					o		o							
						o		o							
	13		e			+ox	+	o					+		
			e			+o	+	o			+	+	+		
	14		e			x	+ x	o							
			e			+ x	+ x	o							
	15					o	+o	o							
						o	+o	o							
	16		e			ox	+ x	o							
			e			+ox	+ x	o							
	17		e			x	+o	o							
						o	o	o							
	18					o	+o	o					+		
						o	+o	o					+		
	19					o	o	o							
						o	o	o							
	20					ox	o	o							
						ox	o	o							
	21					ox	o	o							
						ox	+o	o					+		
	22		e			+ox	+o	x					+		
			e		+	+ox	o	x							
	23		e		+ x	+ x	+ x								
			e			+ x	+o						+		
	24		e	+	+	+ x	+ x								
			e	+		+ x	+ x						+	+	
	25		e			+ x	+ x								
			e			x	+ x	o				+	+		
	26		e			x	+ x								
			e			x	x					+	+		
	27		e			+ x	+ x						+		
			e			+ x	+ x	x					+		
	28		e			+	+ x	x					o		
			e			+	+ x		x			+	+o		
	29		e		+	+	o								
			e	+	+	+	o								
	30		e			+	+o								
			e			+	o						+		
	31						o								
							o								

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

			Area											
	Day		A	B	C	D	E	F	G	H	I	J	K	L
Apr	1	a.m.				o								
		p.m.				o								
	2	e				+ x								
		e				+ x								
	3	e	+	+ x	+	+ x				+	+	+		
		e		+ x	+	x					+			
	4	e	+	+ x	+	+ x				+	+ x			
		e		x		+ x					+ x	+		
	5	e			+	+ x						+ x		
		e				+ x						+ ox		
	6	e			+	+ x						o		
		e				+ x						o		
	7	e				+ x								
		e				x								
	8	e				+ x	+ x							
		e					+ x							
	9	e					+ x							
	10													
	11													
	12													
	13													
	14													
	15										+ x			
											+ x			
	16					+ x					+ x			
						+ x					+ x			
	17										+ x			
						+ x								
	18	e			+	+ x								
						+ x								
	19					+ x								
						+ x								
	20					+ x								
	21													
	22													
	23					+ x								
						+ x	+ x	+						
	24					+ x	+ x		+		+ x			
						+ x	+ x				+ x			
	25	e		+	+	x						+		
		e	+	+	+	+ x								
	26					+ x								
						+ x								
	27					+ x	+ x							
						+ x	+ x							
	28													
	29					+ x	+ ox				+ x			
						+ x	+ ox				ox			
	30					+ x					+ x			
						x					ox			

TABLE 1: Sightings effort from aircraft (+) and purse-seine vessels (x) by half-day by area in the 1979 purse-seine skipjack fishery in New Zealand. Periods of sightings effort aimed at locating skipjack are indicated (e) and periods of poor weather (o) (cont.)

	Day		Area A	B	C	D	E	F	G	H	I	J	K	L
May	1	a.m.					+	+ x			+ x			
		p.m.					+	+ x			+ x			
	2					+ x								
						+ x								
	3					+ x								
						+ x								
	4													
	5					+ x								
						+ x								
	6					+ x								
						x								
	7													
	8						+ x	+			x			
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Results and discussion

Distribution and apparent abundance of skipjack

Skipjack were seen in New Zealand waters from 20 November 1978 to 31 May 1979. Half-day estimates of quantities seen were derived for each area investigated throughout the season and these estimates were totalled to yield overall half-day estimates for all areas (Fig. 2). The half-day estimate was chosen because during each half-day period it was usually possible to eliminate double sightings of schools and so derive good estimates of the quantity of fish present at the surface.

Early season sightings, 20 November–31 December, east and north of Great Barrier Island

The first schools of skipjack were sighted on 20 November 1978 off Great Barrier Island. As in the previous season, the fish were sighted on "the Cross", the position east of Great Barrier Island where latitude 36° S crosses longitude 176° E (see Figs. 1 and 2). The sighting was small (up to 193 t per half-day, 10 schools) and lasted only 4 days. After this time, sightings effort in this area was inadequate to monitor the presence of skipjack (Table 1). There was one further half-day's sightings effort in November (27th), two half-days on 5 December, when 125 t was seen on the Cross, and some effort in the last week of December 1978, with 60 t being seen on the Cross on the 27th. Skipjack were probably present near the Cross for much of this early period, but sightings effort was insufficient to test this likelihood.

Other skipjack seen during this period were in the Bay of Plenty (Fig. 2, area D, 28 November and 27 December) and near North Cape (Fig. 2, area B, 31 December). These small sightings must be viewed in the light of the poor sightings effort coverage during the early season.

Sightings, 4–25 January, east and north of Great Barrier Island

On 4 January 60 t of skipjack were sighted off Cape Brett (Fig. 2, area C; Fig. 3). Some of these fish were caught and they were predominantly large (50 to 55 cm in length). At least some of these fish probably moved to the vicinity of Poor Knights Islands by the 9th.

Also on 9 January, a body of fish was sighted on the Cross. From sightings observations over the next 2 weeks, we suspect that this body moved around the area as shown in Fig. 3.

Two size classes of fish contributed to catches off Great Barrier Island in January, small (40 to 44 cm) and large (50 to 55 cm). It is possible that the body seen off Cape Brett early in January contributed the large fish to these catches; the small fish were probably forerunners, and later representatives, of the body of fish which was located and fished in mid January in off shore north-east Northland waters (see below and Fig. 12, areas C and L).

During this period, therefore, we believe two bodies of fish of different size classes moved through this north-east area in different directions, which resulted in the complex pattern of sightings. Quantities of fish seen varied considerably from day to day, with the largest half-day sighting being 2105 t (Fig. 2, area C).

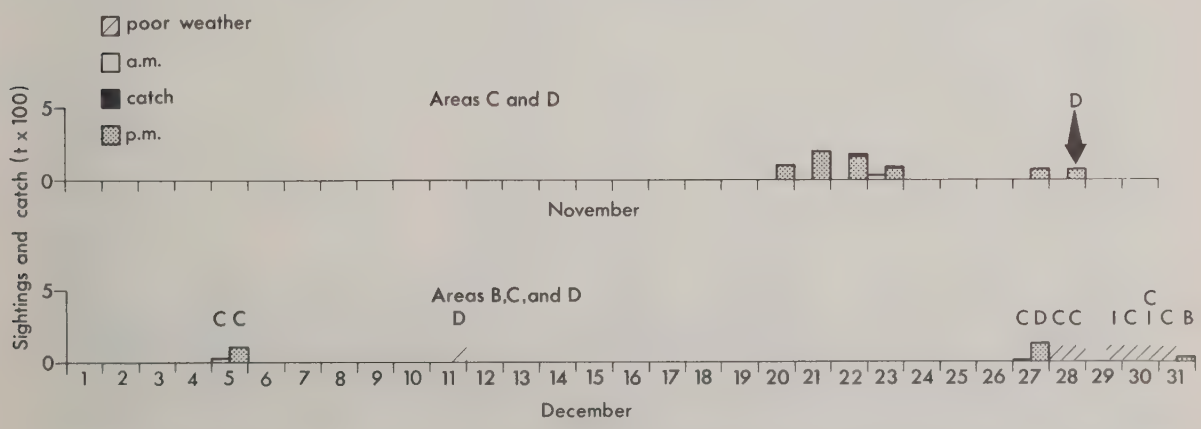


Fig. 2 (above and following pages): Half-day sightings by area and for all areas combined during the 1979 skipjack season in New Zealand.

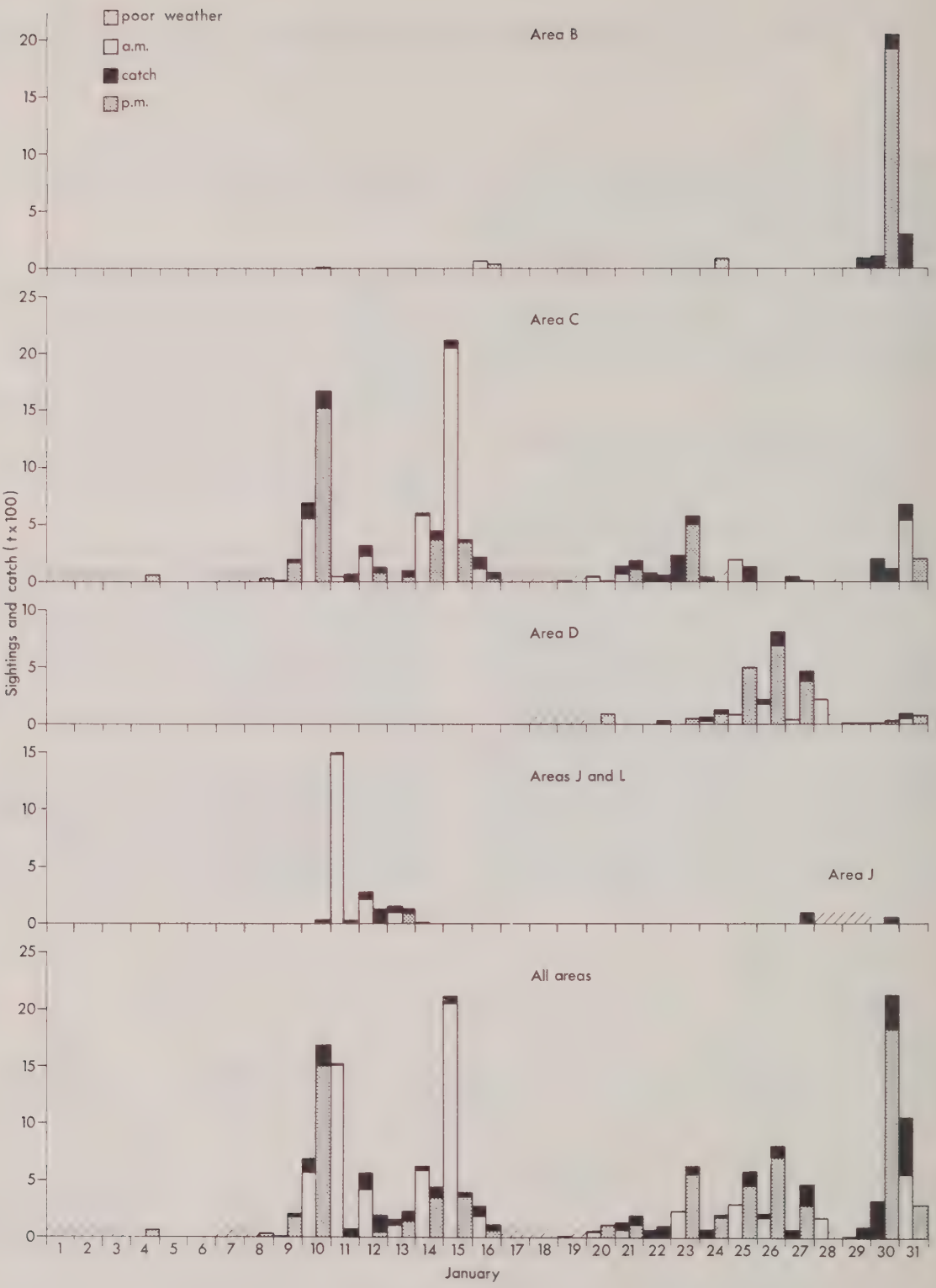
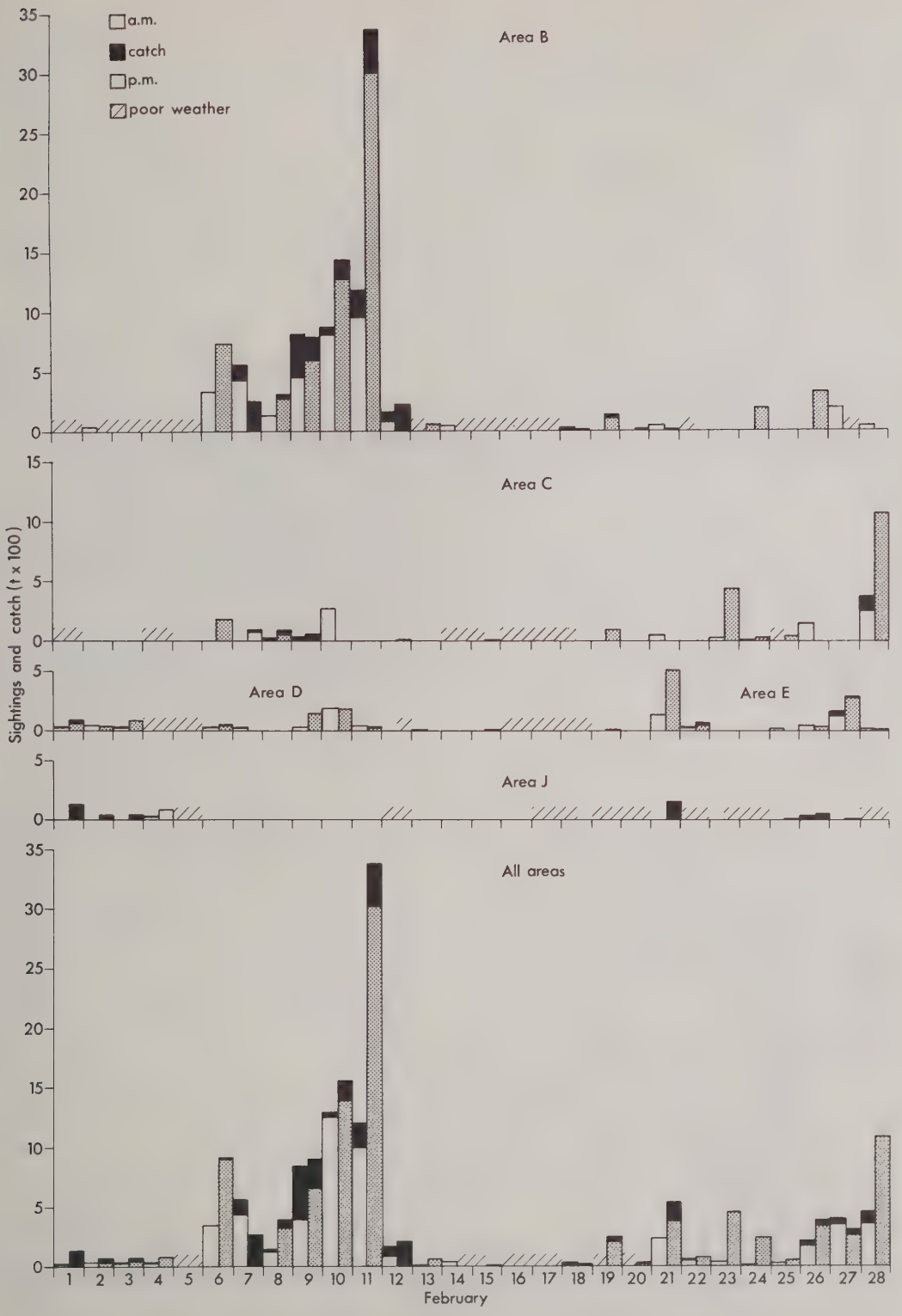


Fig. 2 continued.



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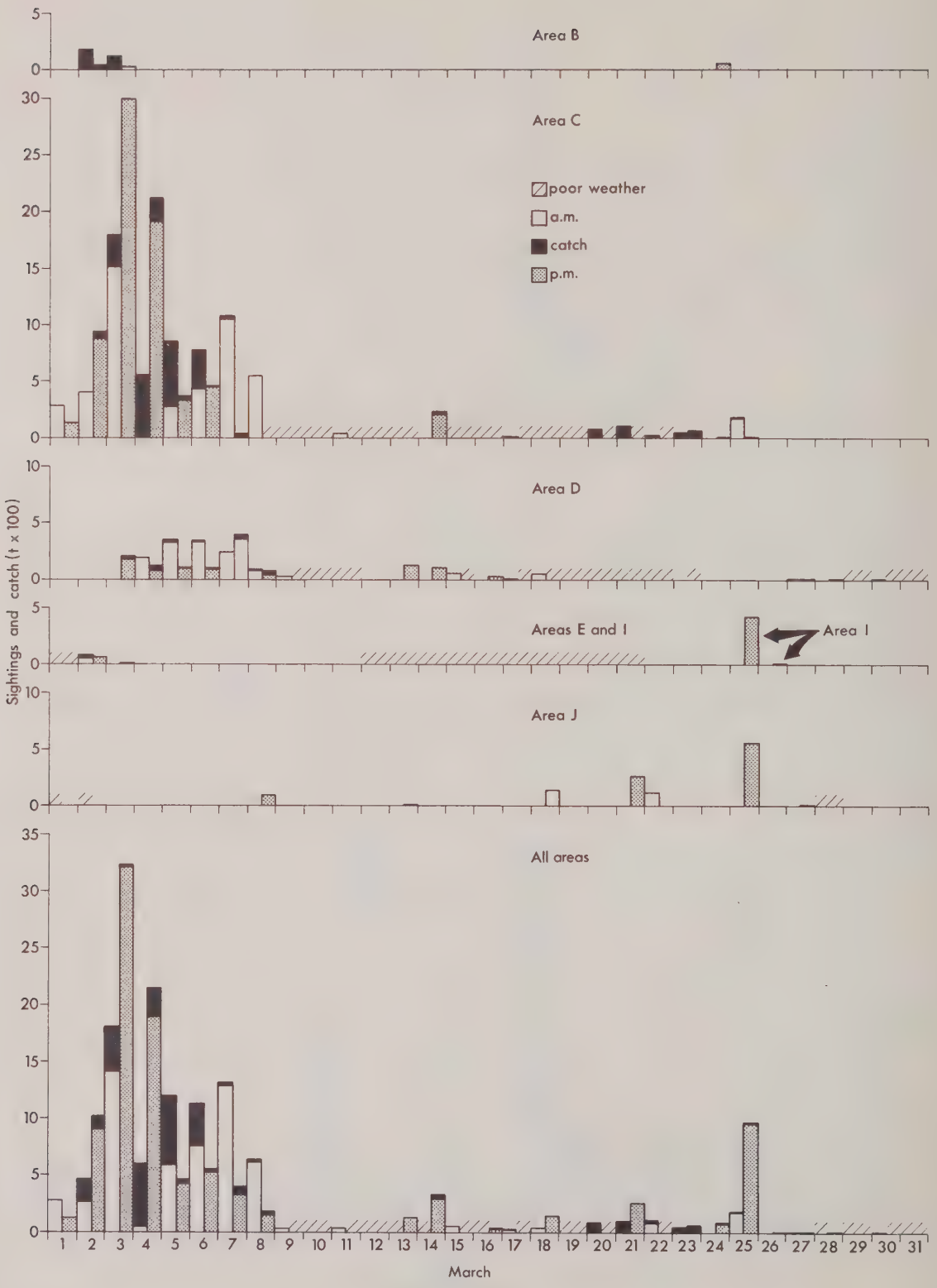

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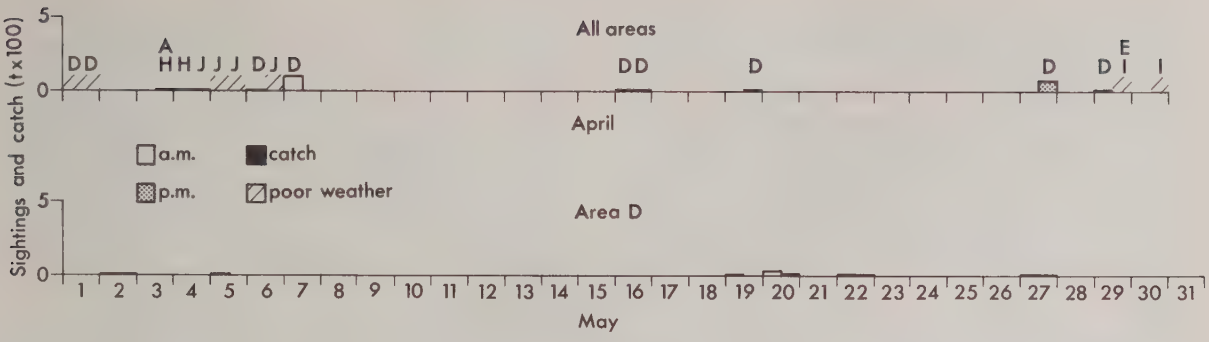


Fig. 2 continued.

Sightings, 10–14 January, off shore north-east Northland

On 10 January, while travelling from American Samoa to New Zealand, *Finisterre* discovered some skipjack schools at the surface 280 km north-east of North Cape (Figs. 1 and 2, area L). The quantity seen increased to 1500 t on the 11th and fell to 10 t on the 14th. The vessels which had been fishing this body then moved to the Cross, and length-frequency analyses suggest that at least some of the fish had also moved here from area L.

Although most fish presumably travelled from area L towards New Zealand below the surface, some were seen travelling at the surface. This was on the 11th at 34° 30′ S, 175° 40′ E and on the 12th at 35° 00′ S, 176° 16′ E. These sightings were made from one of the spotter aircraft. The schools were triangular in shape, with the leading fish at the apex of the triangle. They were travelling fast, which was indicated by a pronounced wake behind the fish.

Season's sightings, east Northland

Although there was sightings effort off both the east and west coasts of Northland, the only skipjack seen were in the east. The first fish were seen on 31 December (Fig. 2, area B). That small sighting was followed by

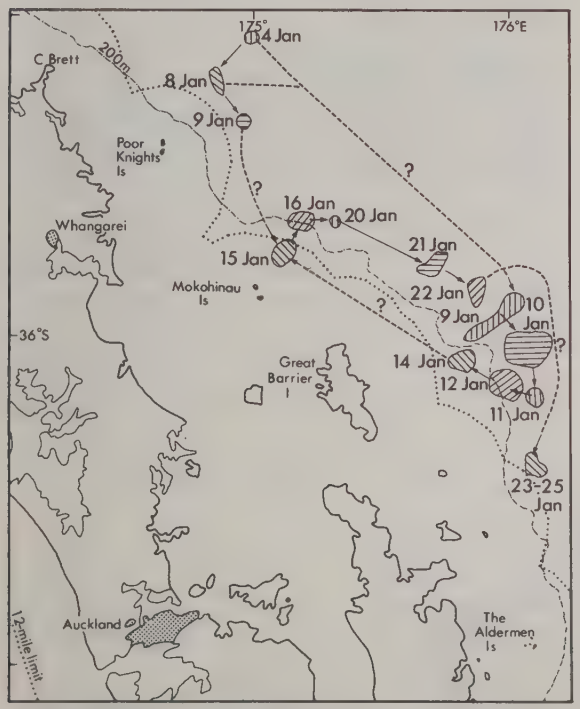


Fig. 3: Daily location of the main concentration(s) of skipjack on the north-east coast of the North Island, 4–25 January 1979.

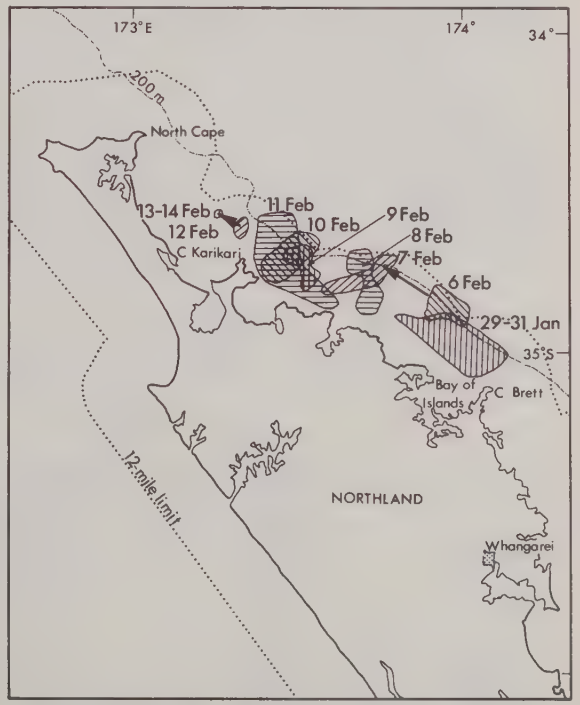


Fig. 4: Daily location of the main concentration of skipjack in Northland waters, 29 January-14 February 1979.

similar sightings on 10, 16, and 24 January. A further small sighting on the 29th signalled the arrival of a large body of skipjack which was to be present in east Northland waters until mid February. This body moved north-west along the 200-m depth contour (Fig. 4), and up to 3400 t of fish was seen at the surface per half-day of sightings effort. The quantity seen rapidly declined after 11 February, partly as a result of a spell of poor weather between the 13th and 18th. Only small sightings were made off this coast during the rest of the season.

Sightings, February to end of season, east and north of Great Barrier Island

Regular sightings surveys off this coast during this period located only small quantities of skipjack through most of February (Fig. 2, area C). However, in late February the quantity seen increased rapidly and large quantities were present until 8 March. During this time the fish moved south-east along the 200-m depth contour from Cape Brett to the Cross (Fig. 5).

Supporting evidence for this movement was provided by tagging data. Of 534 skipjack tagged from a school off Cape Brett on 27 February, 35 were recaptured at 9 sites to the south-east of the tagging site (Fig. 6). Fish tagged to the north and north-west of Great Barrier Island on other occasions showed a similar south-easterly movement (Fig. 7).

Quantities seen fell during 5 days of poor weather in mid March, and thereafter sightings were small, sporadic, and confined to March.

Season's sightings, Bay of Plenty

Although sightings effort was consistent in this area throughout the season, quantities of skipjack seen were small and irregular in their appearance (Fig. 2, area D). The distribution of sightings was also erratic, with small groups of fish showing over wide areas of the Bay of Plenty, often at the same time. Skipjack bodies could not be isolated from the sightings data and neither could movements of skipjack. However, tagging data provided some information on the extent and direction of some movements (Fig. 8). (The straight lines between the tagging and recapture sites in this and other figures simply tie the appropriate sites together and do not necessarily represent actual lines of movement between the sites.)

Season's sightings, East Cape to Hawke Bay

Skipjack schools were found in this area between 19 February and 3 March (Fig. 2, area E). Quantities seen were mainly small, the largest half-day sighting being about 500 t. It is possible that skipjack were present in the area at other times. However, the area received only occasional attention from the spotter aircraft and fishing vessels.

Season's sightings, west coasts of North and South Islands

Few fish were seen off these coasts (Fig. 2, areas H, I, and J), with most being found west of Gannet Island and near New Plymouth in March. Sightings effort was consistently high throughout the season, particularly in Tasman Bay and Golden Bay, where many aerial surveys were flown in conjunction with the fishing operations of Nelson-based vessels seeking a number of pelagic fish species.

Sightings by time of day

The greatest numbers of fish were seen in the afternoon (Table 2). This was partly due to the greater number of daylight hours in the afternoon period during which a maximum sighting could be made.

We reiterate that these sightings were measures of **apparent abundance** which probably included some

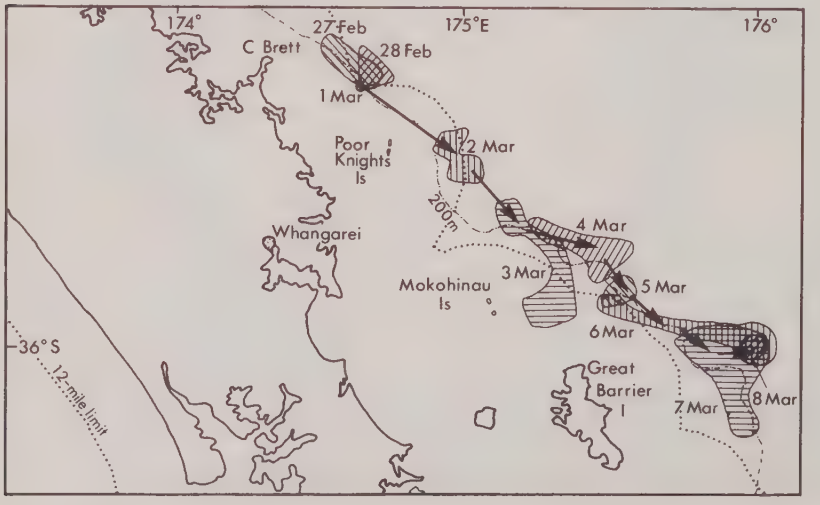


Fig. 5: Daily location of the main concentration of skipjack on the north-east coast of the North Island, 27 February-8 March 1979.

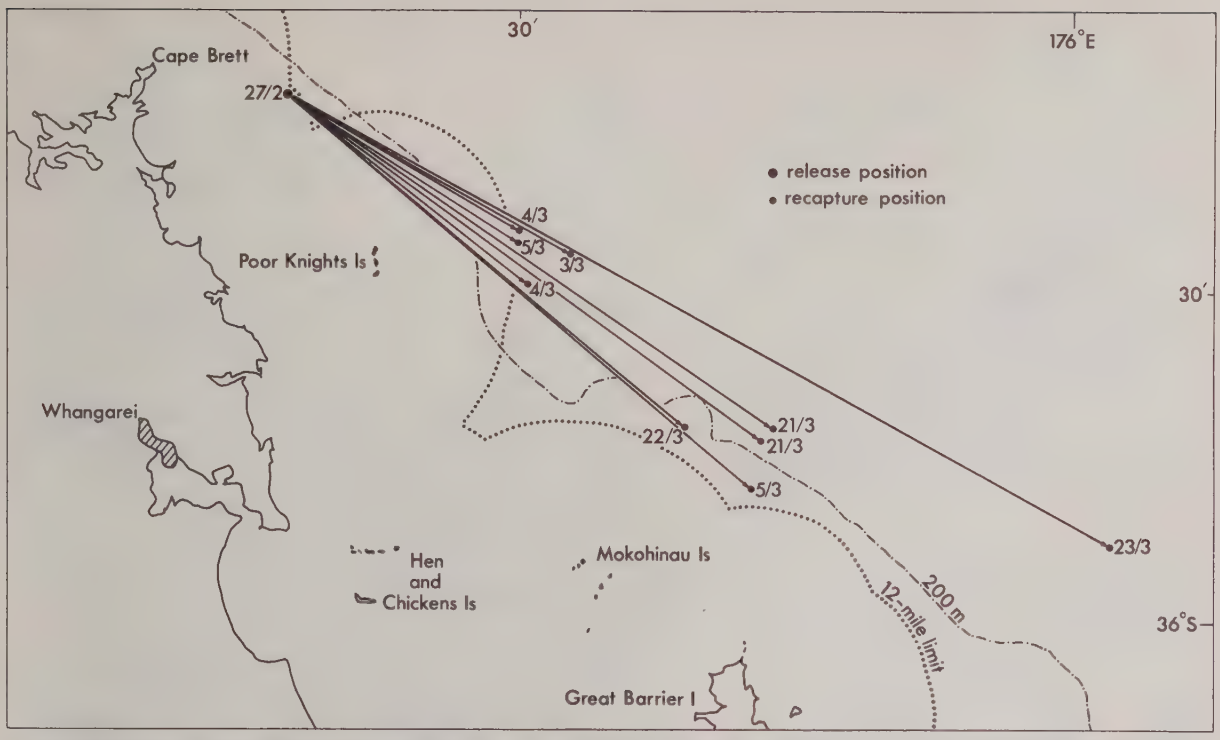


Fig. 6: Release and recapture sites of skipjack tagged on the north-east coast of the North Island on 27 February during the South Pacific Commission's skipjack survey and assessment programme in New Zealand waters, February-March 1979.

multiple quantification of skipjack schools from morning to afternoon, day to day, and even month to month. Therefore the totals in Table 2 do not necessarily represent quantities of fish which could have been taken in the purse-seine fishery, but simply indicate the relative importance of the time of day for fish sightings.

Sightings and the 12-mile fishing limit

Early in the season all skipjack were sighted outside the 12-mile fishing limit as the fish surfaced after migrating to New Zealand from the tropical areas to the north (Table 3). As the season progressed, the proportion of fish inside the limit increased until by February most were there. In March, when the large concentrations of skipjack were moving towards offshore waters preparatory to migrating north again, the proportion of fish outside 12 miles increased. However, April-May sightings (Table 3) show that it was not possible to follow the movement completely into offshore waters. This is because end of season off-shore movements typically culminate in the fish disappearing from the surface. We assume that migrations out of New Zealand waters occur at depth.

Over the whole season nearly 60% of the skipjack appeared inside the 12-mile fishing limit and the remainder outside.

TABLE 2: Monthly skipjack sightings by time of day in the 1979 purse-seine skipjack fishery in New Zealand

	Morning		Afternoon-evening		
Month	Sightings (t)	% each period's sightings	Sightings (t)	% each period's sightings	Total (t)
Nov	66	7.5	819	92.5	885
Dec	35	12.7	240	87.3	275
Jan	8 759	48.2	9 409	51.8	18 168
Feb	6 193	34.1	11 967	65.9	18 160
Mar	8 598	45.4	10 339	54.6	18 937
Apr	119	58.3	85	41.7	204
May	65	68.4	30	31.6	95
Nov-May	23 835	42.0	32 889	58.0	56 724

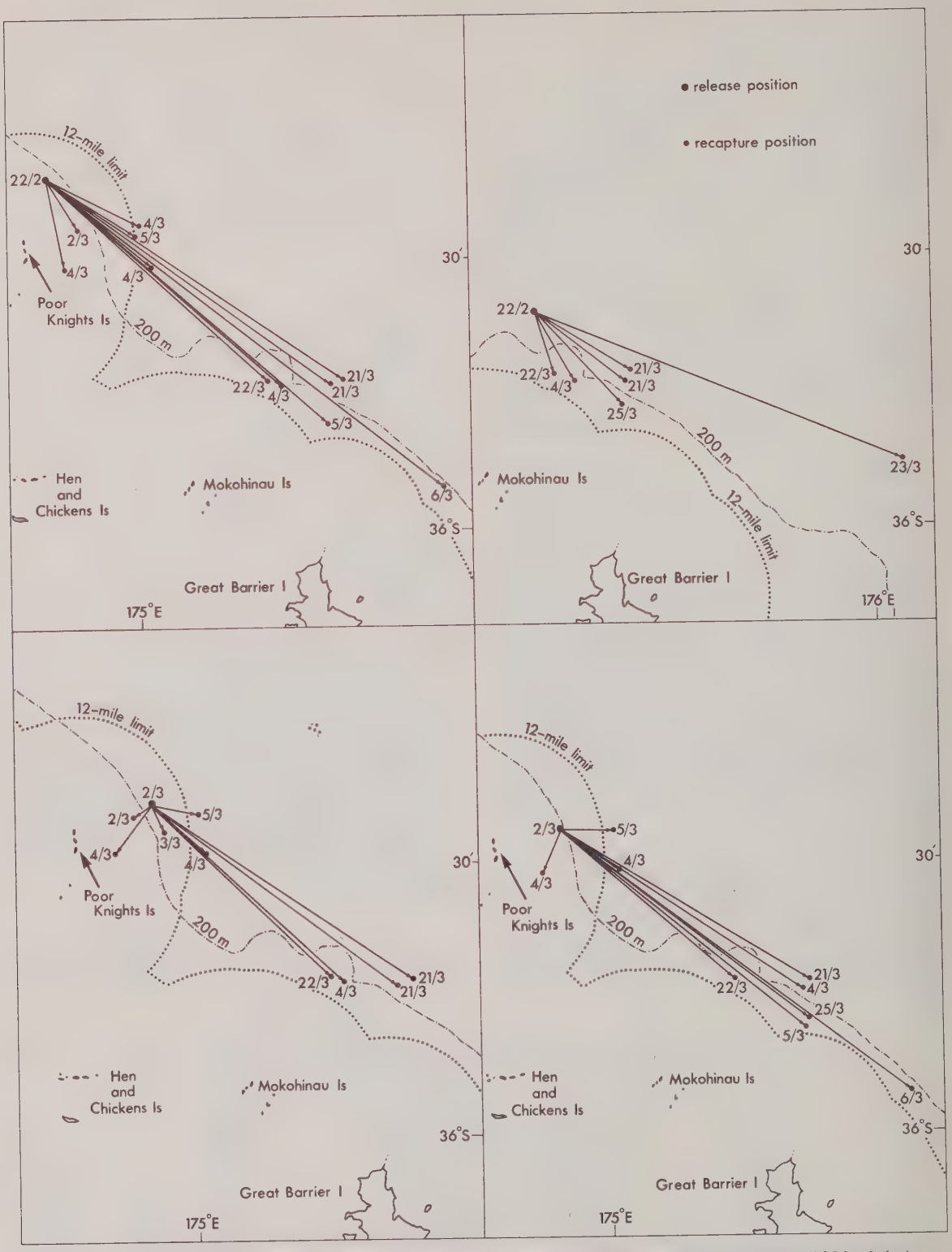


Fig. 7: Release and recapture sites of skipjack tagged on the north-east coast of the North Island on 22 February and 2 March during the South Pacific Commission's skipjack survey and assessment programme in New Zealand waters, February-March 1979.

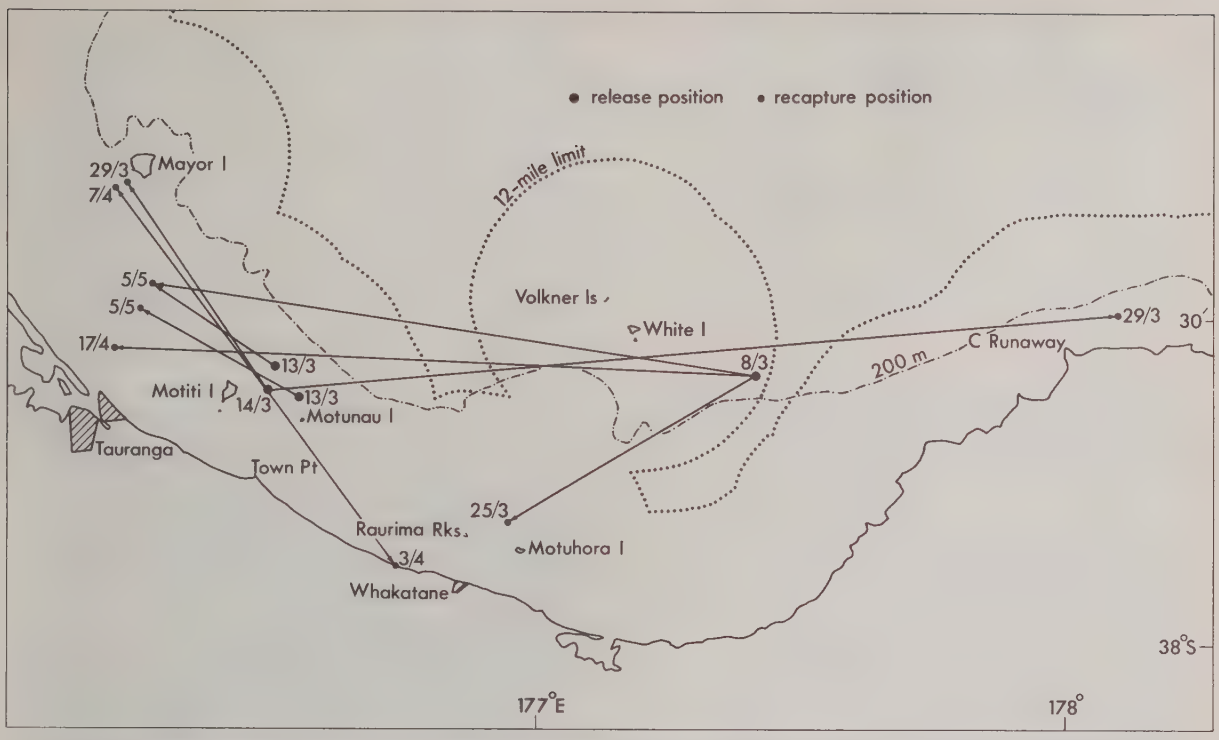


Fig. 8: Release and recapture sites of skipjack tagged in the Bay of Plenty during the South Pacific Commission's skipjack survey and assessment programme in New Zealand waters, February-March 1979.

Sightings, 1976, 1977, 1978, and 1979 seasons

Fewer skipjack were seen at the surface during 1979 than in the previous three seasons (Table 4), probably partly because there were fewer days of sightings effort in 1979 than in the other seasons. This resulted largely from the often long spells of poor weather which curtailed sightings effort (see Table 1 and Fig. 2). In 1979 more fish were seen per day of sightings effort than in 1977, but fewer than in 1976 and 1978. As in the other seasons, most fish were seen from January to March.

Fluctuations in apparent abundance

These were considerable and coincided largely with the appearance and disappearance of various bodies of skipjack which moved through the New Zealand area during the season (Figs. 2–5). Reports on earlier seasons indicate that similar fluctuations occurred during those seasons. However, the underlying reasons for the fluctuations remain unclear.

Apparent abundance and catch

A summary of the data in Fig. 2 (see Table 5) shows that of skipjack sighted, only a small proportion was caught; this ranged from 2.5% in the morning in April to 25.5% in the morning in March. On average, about 21% of the fish seen during the mornings was caught and 12% in the afternoons. By this measure, the resource seemed to be under little pressure from fishing.

TABLE 3: Monthly skipjack sightings in relation to the 12-mile fishing limit in the 1979 purse-seine skipjack fishery in New Zealand

	Inside 12 miles		Outside 12 miles		
Month	Sightings (t)	% each period's sightings	Sightings (t)	% each period's sightings	Total (t)
Nov	0	0	819	100.0	819
Dec	0	0	240	100.0	240
Jan	4 089	43.4	5 320	56.6	9 409
Feb	10 095	84.4	1 872	15.6	11 967
Mar	5 197	50.3	5 142	49.7	10 339
Apr	85	71.4	34	28.6	119
May	65	100.0	0	0	65
Nov-May	19 531	59.3	13 427	40.7	32 958

TABLE 4: Monthly skipjack sightings in New Zealand, 1976 to 1979, computed by totalling maximum half-day sightings*. (Data for 1976 and 1977 from Clement (1978) and for 1978 from Habib, Clement, and Fisher (in press))

Season	Period of sightings effort	No. of days of sightings effort	Mean quantity sighted per day (t)	Quantity sighted Oct (t)	Quantity sighted Nov (t)	Quantity sighted Dec (t)	Quantity sighted Jan (t)	Quantity sighted Feb (t)	Quantity sighted Mar (t)	Quantity sighted Apr (t)	Quantity sighted May (t)	Total quantity sighted (t)
1976	7 Oct-27 Mar	102	545	3 337 (6%)†	1 112 (2%)	9 455 (17%)	13 905 (25%)	17 798 (32%)	10 012 (18%)	–‡	–	55 619
1977	21 Nov-14 Apr	139	285	-	0	1 190 (3%)	12 697 (32%)	9 126 (23%)	15 871 (40%)	793 (2%)		39 677
1978	25 Dec-31 May	131	523	-		1 225 (1.7%)	25 286 (37%)	11 779 (17.2%)	29 674 (43.3%)	342 (0.5%)	258 (0.3%)	68 564
1979	20 Nov-27 May	91	362	–	819 (2.4%)	240 (0.7%)	9 409 (28.6%)	11 967 (36.3%)	10 339 (31.4%)	119 (0.4%)	65 (0.2%)	32 958

* For example, in November of the 1979 season, sightings were made in the morning on the 26th and in the afternoon on the 20th to the 23rd and the 27th and 28th (see Fig. 2); these sightings totalled 819 t for that month.

† Percentage of season's total.

‡ No sightings effort.

Real abundance

If the concept of bodies of skipjack is accepted (see page 9), a measure of real abundance can be gained for each body by addition of the largest half-day sighting of each body to the quantity of fish caught from it before the largest sighting (Table 6). For example, the body which moved north-west through area B between 29 January and 14 February (see Figs. 2 and 4) produced a maximum sighting of 3365 t on the afternoon of 11 February. Before that, the purse-seine vessels had caught 2262 t from the body. The estimated amount of fish in that body was the sum of the maximum sighting and the catch made before that sighting, that is, 5627 t.

By summing similar estimates for all bodies seen and adding the isolated fish which probably did not contribute to any of the main bodies, it was possible to derive a measure of real abundance of fish for the season. This measure, which was 19 088 t, is largely free of double sightings, as it was based on half-day sightings which recorded schools only once.

This measure of real abundance should be regarded as a minimum, as it is unlikely that the largest half-day sightings recorded all fish in the bodies or that all bodies which passed through the New Zealand area were seen. Further, little account was taken of the large number of scattered fish which were present throughout the New Zealand area during the season.

Skipjack schools

Almost 1100 schools were seen during the 1979 skipjack season. On average, 12 schools were seen per day of sightings effort, and the mean size of school was about 30 t. Notable sightings of large schools are listed in Table 7.

Catch, effort, and catch per unit of effort

The season was about 5 months long, beginning in November and finishing in April. During this time the fleet worked 1042 season-days (Fig. 9). These comprised days searching and fishing, days lost through poor weather, days spent on repairs, survey, discharging, and taking on stores, days travelling, and days taken off.

During the 419 days fished, 8975 t of skipjack were caught; 43 t in November, 3278 t in January, 2892 t in February, 2759 t in March, and 3 t in April (Fig. 10). No fish were caught in December.

Effort, measured as number of season-days, peaked in February-March; the other measures of effort – days fished, sets, and successful sets – peaked in January (Fig. 10, left-hand axis). The reverse held for catch rates: the best catches per season-day were in January, when vessels averaged 10.9 t, and the best catches per

TABLE 5: Quantities of fish seen and caught by half-day in the 1979 purse-seine skipjack fishery in New Zealand

Month	Morning			Afternoon-evening		
	Quantity sighted (t)	Quantity caught (t)	% caught of quantity sighted	Quantity sighted (t)	Quantity caught (t)	% caught of quantity sighted
Nov	66	0	0	819	43	5.2
Dec	35	0	0	240	0	0
Jan	8 759	1 703	19.4	9 409	1 575	16.7
Feb	6 193	1 148	18.5	11 967	1 744	14.6
Mar	8 598	2 194	25.5	10 339	565	5.5
Apr	119	3	2.5	85	0	0
May	65	0	0	30	0	0
Nov-May	23 835	5 048	21.2	32 889	3 927	11.9

day fished, set, and successful set in March (vessel averages of 24.1 t per day fished, 17 t per set, and 50.2 t per successful set) (Fig. 10, right-hand axis).

The rise and fall of catch and effort probably resulted partly from seasonal fluctuations in the number of vessels in the fishery (2 in November, 2 in December, 12 in January and February, 10 in March, 2 in April). Catch and effort also rose and fell because of seasonal fluctuations in the skipjack resource, and also in relation to the availability of that resource to the major portion of the fishing fleet which was restricted to operating outside the 12-mile fishing limit.

Catch and effort by area

Seining was done in six areas on the New Zealand coast (see Fig. 1). Almost half of the season's catch (4372 t) was taken in area C (east and north of Great Barrier Island) with about half of the fishing effort. Most of the fishing in this area occurred in January and March, and catch rates for the area were close to the season's means (Table 8).

Area B (east Northland) was next in importance; one-third of the catch was caught here with about one-sixth of the fishing effort. The fishing in this area was in February, and catch rates were substantially higher than the season's means.

Small quantities of skipjack were also caught in the Bay of Plenty, from East Cape to Hawke Bay, and off the west coast of the North Island. It is significant that only small catches were taken off the west coast and only small quantities of fish were seen there. This contrasted with previous years, when large catches were made and large quantities of fish were seen.

TABLE 6: Estimated minimum real abundance of skipjack in the New Zealand region during the 1979 season

Period that bodies or distinguishable quantities present	Area	Max. sighting (t)	Catch from body before max. sighting (t)	Estimated min. real abundance (t)
31 Dec–24 Jan	B	85	0	85
29 Jan–14 Feb	B	3 365	2 262	5 627
Late Feb	B	217	84	301
Mar	B	125	263	388
20–28 Nov	C	250	0	250
Dec	C	115	0	115
4–25 Jan	C	2 105	652	2 757
Feb	C	432	150	582
27 Feb–8 Mar	C	2 995	413	3 408
27 Nov–1 Dec	D	100	0	100
Jan	D	802	203	1 005
Feb	D	148	83	231
Mar	D	391	88	479
Apr	D	90	0	90
May	D	40	0	40
Feb–Mar	E	517	15	532
Apr	H	17	0	17
Mar	I	417	0	417
Jan	J	110	0	110
Feb	J	165	314	479
Mar	J	544	0	544
Apr	J	1	0	1
10–14 Jan	L	1 500	30	1 530
			Total	19 088

TABLE 7: Notable sightings of large schools in the 1979 purse-seine skipjack fishery in New Zealand

Date	No. of schools	Size of schools (t)	General area	Position
31 Jan	4	100–150	N of Bay of Islands	35°05′ S, 174°08′ E
6 Feb	3	200–250	E of Cavalli Is	34°57′ S, 174°24′ E
7 Feb	3	150–200	NW of Cavalli Is	34°45′ S, 173°48′ E
9 Feb	2	150	NE of Cavalli Is	34°52′ S, 174°10′ E
10 Feb	10	100–250	NW of Cavalli Is	34°47′ S, 173°44′ E
11 Feb	11	150–250	NW of Cavalli Is	34°47′ S, 173°33′ E
28 Feb	4	100–150	NW of Cavalli Is	34°44′ S, 173°43′ E
28 Feb	2	100–150	E of Poor Knights Is	35°24′ S, 174°58′ E
2 Mar	6	100–250	E of Poor Knights Is	35°27′ S, 174°53′ E
3 Mar	2	150–200	E of Poor Knights Is	35°26′ S, 174°54′ E
3 Mar	9	150–250	NE of Mokohinau Is	35°43′ S, 175°23′ E
4 Mar	7	100–200	NE of Mokohinau Is	35°42′ S, 175°28′ E
5 Mar	2	100–150	NE of Mokohinau Is	35°41′ S, 175°27′ E
6 Mar	1	150	Bay of Plenty	37°37′ S, 177°00′ E
6 Mar	3	100–150	NE of Mokohinau Is	35°40′ S, 175°28′ E
6 Mar	2	100–200	E of Great Barrier I	36°14′ S, 176°04′ E
7 Mar	6	100–200	E of Great Barrier I	36°13′ S, 176°04′ E

An interesting new area to be fished was that about 280 km north-east of North Cape (Fig. 1, area L). There, 5 days of fishing yielded 299 t of skipjack at catch rates above the season's means.

Catch and effort by depth

Skipjack were caught where bottom depths were between 60 and 3000 m (Table 9). However, most (7834 t) were caught where the water was 100 to 399 m deep. There the greatest effort (sets) was expended and the highest catch rates (per set, per successful set) recorded. However, though making small catches, the vessels also recorded high catch rates in the deeper waters of 400 to 599 m. The areas where most fish were caught were above the edge of the continental shelf.

Catch and effort by time of day

Sets were made between 6.30 a.m. and 9.30 p.m. Over half the fish (4963 t) were taken in the morning (6.00 to 11.59 a.m.), about one-third (3285 t) in the afternoon (noon to 5.59 p.m.), and the remainder (727 t) in the evening. Half of the sets were made in the afternoon, about one-third in the morning, and the remainder in the evening. However, catch rates (per set, per successful set) were highest in the morning, then the afternoon, then the evening.

Catch and effort by moon phase

Almost three-quarters of the season's catch was taken during the new moon and first quarter phases, with about half of the season's effort (sets) (Table 10). Catch rates were also high during those periods, particularly during new moon, when the average catch per set was 21.2 t and per successful set 53.2 t. Fishing was not as productive in the last quarter and even less so during full moon.

Catch and effort by sea surface temperature

Skipjack were caught in areas where surface water temperatures ranged from 17° to 22.9°C (Table 11). However, most (8926 t) were caught in 19° to 22.9°C water (designated "skipjack water" by us). This water was present within the range of skipjack on the New Zealand coast for more time during the skipjack season than the cooler water. As a result, most of the fishing effort (98.9% of sets, 98.6% of successful sets, searching and fishing during 20 of the 22 fortnightly periods

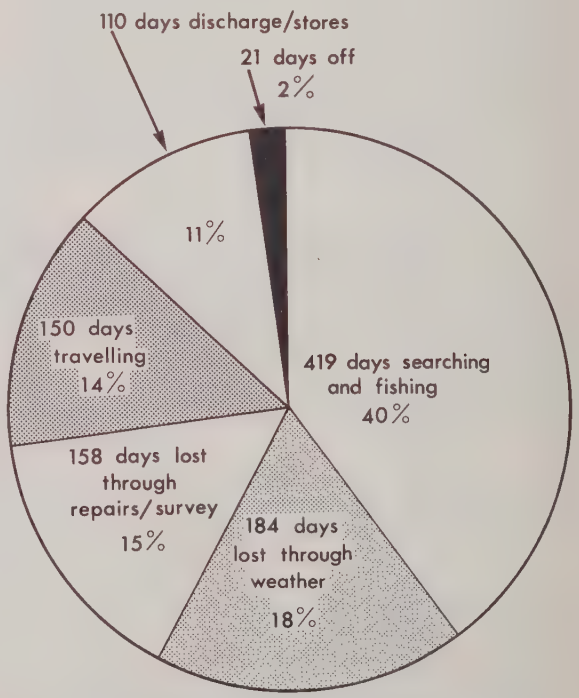


Fig. 9: Days fished and days lost in the 1979 purse-seine skipjack fishery in New Zealand.

TABLE 8: Catch, effort, and catch per unit of effort by area in the 1979 purse-seine skipjack fishery in New Zealand

	Catch		Effort								Catch/effort			
			Season-days		Days searching and fishing		Sets		Successful sets		Catch per season-day	Catch per day searching and fishing	Catch per set	Catch per successful set
Area	Quantity (t)	% of total	No.	% of total	No.	% of total	No.	% of total	No.	% of total	(t)	(t)	(t)	(t)
A	—*	—	7.0	0.7										
B	2 947	32.8	100.5	9.6	69.5	16.6	123	18.4	60	21.4	29.3	42.4	24.0	49.1
C	4 372	48.7	446.5	42.9	219.5	52.4	323	48.4	132	47.0	9.8	19.9	13.5	33.1
D	680	7.6	203.5	19.5	70.5	16.8	114	17.1	38	13.5	3.3	9.6	6.0	17.9
E	120	1.3	112.0	10.7	21.5	5.1	36	5.4	11	3.9	1.1	5.6	3.3	10.9
F	—	—	2.5	0.2										
G	—	—												
H	—	—												
I	—	—	8.0	0.8										
J	557	6.2	62.0	6.0	26.0	6.2	40	6.0	18	6.4	9.0	21.4	13.9	30.9
K	0	0	4.0	0.4	1.5	0.4								
L	299	3.3	11.5	1.1	10.5	2.5	31	4.6	22	7.8	26.0	28.5	9.6	13.6
			84.5†	8.1										
Total	8 975		1 042.0		419.0		667		281		8.6	21.4	13.5	31.9

* No fishing.
† Outside New Zealand — days spent travelling to and from, and discharging fish at, the cannery in American Samoa.

TABLE 9: Catch, sets, and set success by bottom depth in the 1979 purse-seine skipjack fishery in New Zealand

Depth (m)	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
0–99	229	2.6	39	5.8	5.9	17	6.0	13.5
100–199	2 946	32.8	248	37.2	11.9	83	29.5	35.5
200–299	3 593	40.0	241	36.1	14.9	107	38.1	33.6
300–399	1 295	14.4	72	10.8	18.0	33	11.7	39.2
400–499	248	2.8	13	1.9	19.1	8	2.8	31.0
500–599	268	3.0	12	1.8	22.3	7	2.5	38.3
600–699	34	0.4	4	0.6	8.5	2	0.7	17.0
700–799	0	0	2	0.3	0	0	0	0
800–899	0	0	1	0.1	0	0	0	0
900–999	0	0	1	0.1	0	0	0	0
1 000–3 000	362	4.0	34	5.1	10.6	24	8.5	15.1
Total	8 975		667		13.5	281		31.9

TABLE 10: Catch, sets, and set success by moon phase in the 1979 purse-seine skipjack fishery in New Zealand

Moon phase	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)
New moon	3 194	35.6	151	22.6	21.2	60	21.4	53.2
First quarter	3 321	37.0	227	34.0	14.6	99	35.2	33.5
Full moon	916	10.2	134	20.1	6.8	55	19.6	16.7
Last quarter	1 544	17.2	155	23.2	10.0	67	23.8	23.0
Total	8 975		667		13.5	281		31.9

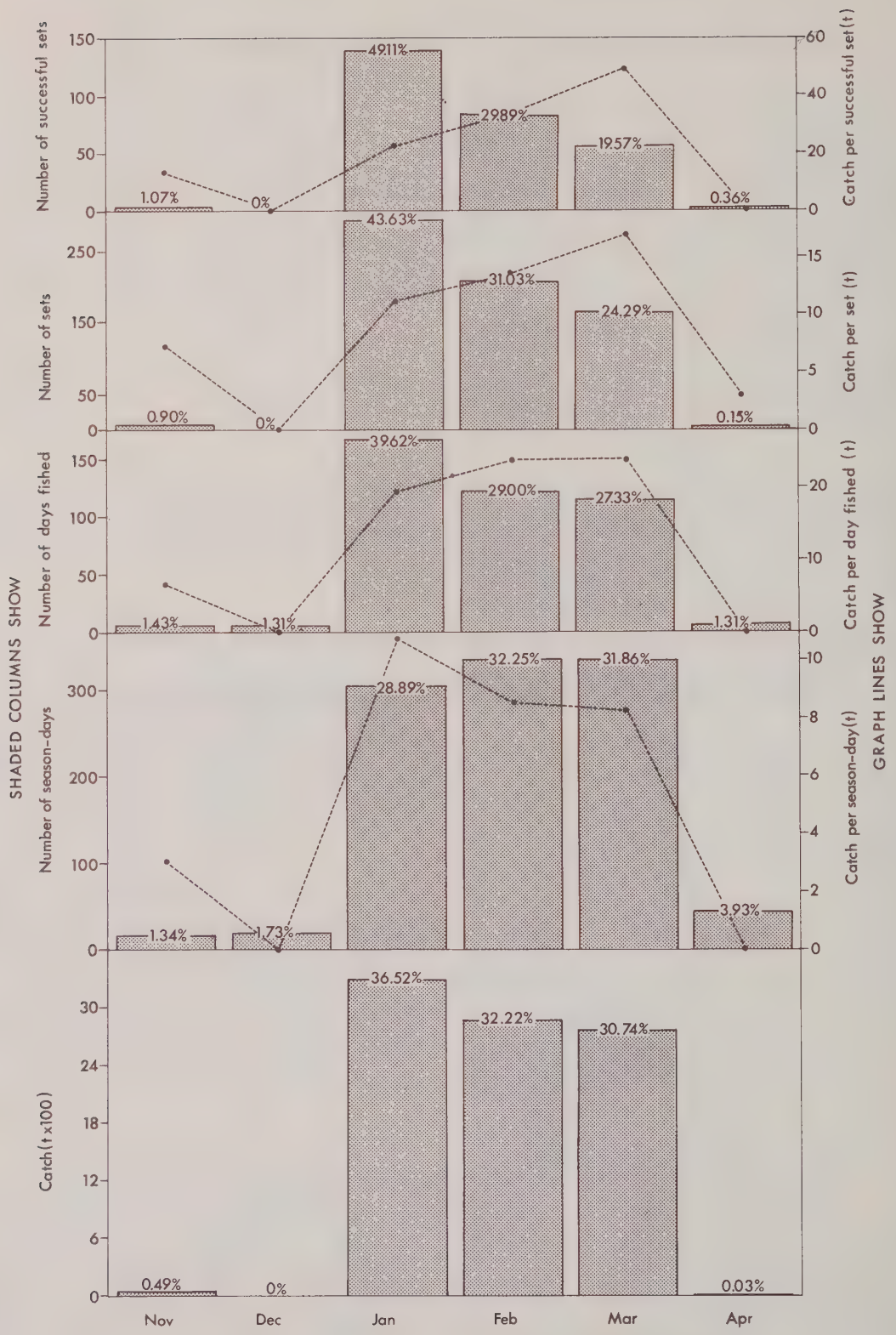


Fig. 10: Monthly catch, effort, and catch per unit of effort in the 1979 purse-seine skipjack fishery in New Zealand.

TABLE 11: Catch, sets, set success, and fishing effort (searching and fishing) by sea surface temperature in the 1979 purse-seine skipjack fishery in New Zealand (temperatures from shipboard records)

Water temp. range (°C)	Catch (t)	% of total	Sets	% of total	Catch per set (t)	Successful sets	% of total	Catch per successful set (t)	Fishing effort expended during the fortnightly periods								
									12/11-25/11	26/11-9/12	10/12-23/12	24/12-6/1	7/1-20/1	21/1-3/2	4/2-17/2	18/2-3/3	4/3-17/3	18/3-31/3	1/4-14/4
17.0–17.9	44	0.5	6	0.9	7.3	3	1.1	14.7	✓										
18.0–18.9	5	0.1	1	0.1	5.0	1	0.4	5.0				✓							
19.0–19.9	170	1.9	11	1.6	15.5	4	1.4	42.5					✓			✓		✓	
20.0–20.9	3 393	37.8	267	40.0	12.7	110	39.1	30.8					✓	✓	✓	✓	✓	✓	✓
21.0–21.9	4 557	50.8	317	47.5	14.4	124	44.1	36.8					✓	✓	✓	✓	✓	✓	
22.0–22.9	806	9.0	65	9.7	12.4	39	13.9	20.7					✓	✓	✓			✓	
Total	8 975		667		13.5	281		31.9											

fished during the season) was expended in skipjack water. Catch rates, too, were highest in that water.

Sea surface temperature measurements from satellites in relation to the skipjack fishery

Weekly satellite sea surface temperature charts for the New Zealand region for 24 October 1978 to 29 May 1979 are presented (Fig. 11). The charts, with isotherms at 1.0°C intervals, cover the 1979 skipjack season and some time before and after the season. Skipjack water (as defined above) is shaded to simplify tracing its distribution through the season.

This water first appeared on the coast in early December and extended as a tongue down the north-east North Island to The Aldermen Islands. By late December it extended down the east coast to the Bay of Plenty and by early February to Cook Strait. In the west, warming began in late December north of Reef Point and progressed southwards to the north of the South Island by late February. From mid April there was a general cooling, and by the end of May there was little skipjack water on the New Zealand coast.

Some of the sea surface temperature charts from satellites (see Fig. 11, charts for the weeks ending 5, 12, and 19 December, 2 January, and 6 March and all April and May charts) suggest that there was some mass "movement" of a tongue of warm water south to and north from New Zealand during the season. Eggleston and Paul (1978) found a similar occurrence in 1977 and suggested that such a movement may have been more apparent than real, resulting from a progressive southward warming (and by implication a northward cooling late in the season) rather than movement of surface water. We also believe that there was both progressive warming and cooling and some water movement.

Skipjack were generally found and fished in skipjack water. Notable exceptions were the fish in the cooler water in areas C and D in November (see Figs. 2 and 11). The early season occurrence of skipjack in cold water is becoming a regular feature of the New Zealand fishery. There were similar occurrences in October-November 1975 (Clement 1976) and November-December 1976 (Clement 1978). During these early "showings", the water has been as cold as 16°C (see Figs. 3–6 *in* Eggleston and Paul 1978). This is interesting in the light of the commonly held belief that the lower temperature limit of skipjack is about 18°C (Barkley, Neill, and Gooding 1978).

Given the high degree of correlation between the distribution of skipjack and skipjack water, the satellite data are useful in leading to a broad understanding of skipjack distribution in New Zealand in summer. If they were available in time, they would also have some predictive value.

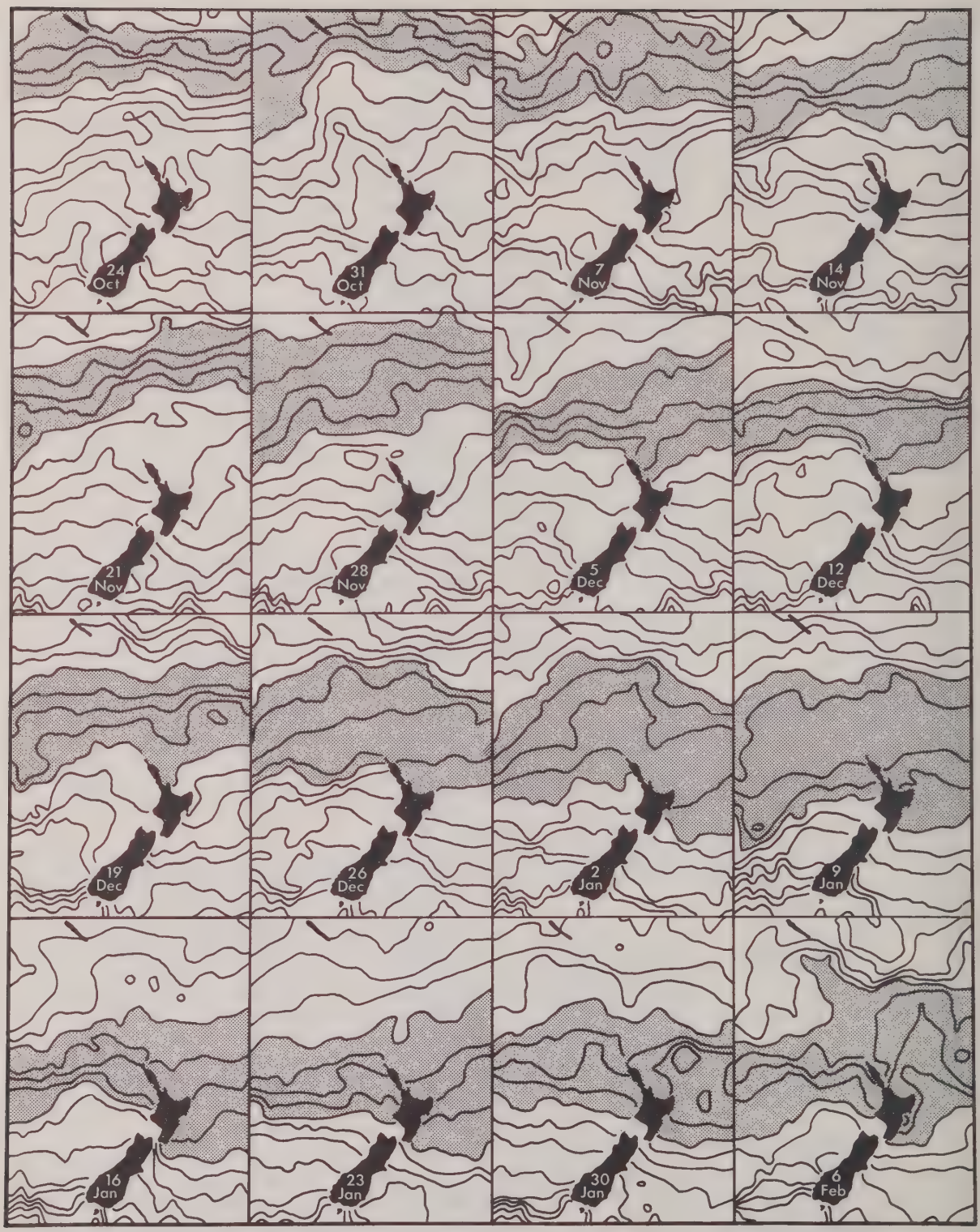
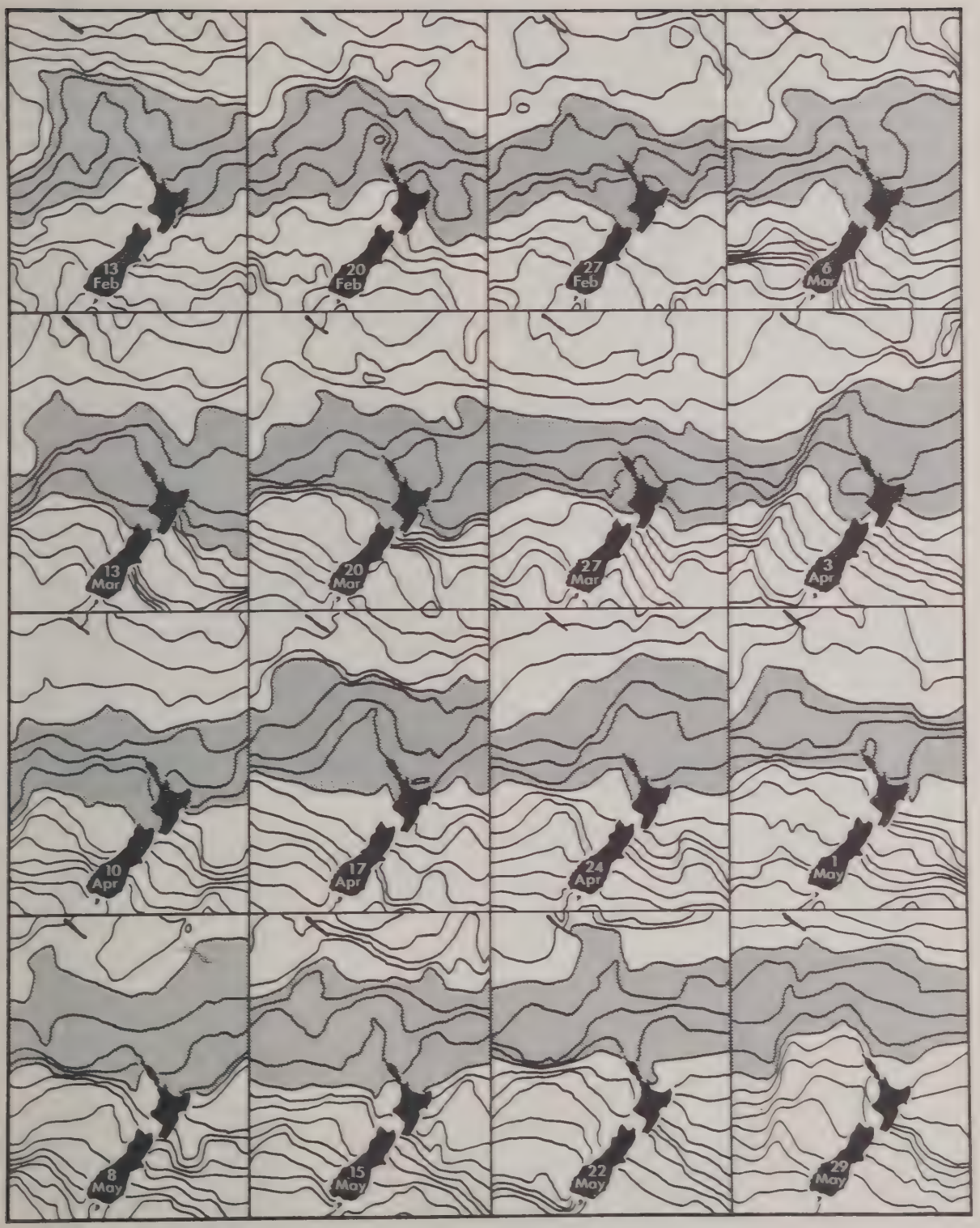


Fig. 11 (above and right): Weekly sea surface temperature charts for the New Zealand region, from satellite measurements, for the 1979 skipjack season. Water of 19°–23°C ("skipjack water") is shaded; isotherms are at 1°C intervals.


13 Feb
20 Feb
27 Feb
6 Mar
13 Mar
20 Mar
27 Mar
3 Apr
10 Apr
17 Apr
24 Apr
1 May
8 May
15 May
22 May
29 May

Purse-seine fishing and the 12-mile limit

Almost three-quarters of the season's catch (6276 t) was taken outside the 12-mile limit and the remainder (2699 t) inside (Table 12). As in past seasons, fishing was concentrated along the 200-m depth contour, which was close to the 12-mile limit (see set positions, Fig. 1).

The distribution of catches in relation to the 12-mile limit reflected the enforced distribution of the greater part of the fishing fleet rather than the distribution of the resource. All the large vessels (except *Finisterre*) were restricted to fishing outside the limit, but nearly 60% of all skipjack were found inside the limit (see Sightings and the 12-mile fishing limit, page 23).

Some measures of the importance of the in-shore waters can be gained from the performance of *Finisterre*: she took three-quarters of her catch inside 12 miles and one-quarter outside. In addition, she caught 1.8 times more fish than the other large vessels. Past performances have shown that *Finisterre* is about average in her size class (data in MAF files). It seems that *Finisterre* performed better during this season because she had unrestricted access to the skipjack resource. The lack of any real competition for the resource inside 12 miles must also have contributed to her performance.

There is little doubt that, without restriction, there would have been much more fishing inside the limit and a substantially greater season's catch.

TABLE 12: Catch and set data for catches made inside the 12-mile limit by large (Il) and small (Is) purse-seine vessels and outside the limit by large (Ol) and small (Os) vessels in the 1979 purse-seine skipjack fishery in New Zealand

Vessel	Catch (t) (% of season's total)	Sets (% of season's total)	Catch per set (t)	Successful sets (% of season's total)	Catch per successful set (t)
Il	1 914 (21.3)	51 (7.7)	37.5	30 (10.7)	63.8
Is	785 (8.7)	145 (21.7)	5.4	46 (16.3)	17.1
Ol	5 715 (63.7)	356 (53.4)	16.1	166 (59.1)	34.4
Os	561 (6.3)	115 (17.2)	4.9	39 (13.9)	14.4
Total	8 975	667	13.5	281	31.9

Biology

Length-frequency distributions

During 1979, MAF observers on the purse seiners measured over 25 000 skipjack (0.6% of the estimated total number of fish caught during the season). Catches sampled by area were 32 in B, 80 in C, 5 in D, 15 in J, and 13 in L. All length measurements were grouped by 2-week intervals by area to provide a record of the length composition of the catches throughout the season (Fig. 12). This figure also shows the changes in the location of the fishery during the season.

The first catches were made in November north and east of Great Barrier Island (area C). These contained mainly large 55- to 65-cm fish (3.6 to 6.2 kg in weight). By early January most fish in this area were 45 to 55 cm (1.8 to 3.6 kg). These fish persisted in the catches until late January, when they were joined by a smaller size group of 40- to 50-cm fish (1.3 to 2.6 kg). By mid February the small fish dominated the catches in this area and continued to do so for the rest of the season.

Fishing began off east Northland (area B) at a time that corresponded with the arrival in New Zealand of the same small size group that was fished in area C. As in area C, the small fish dominated the Northland catches and also catches in areas J (west coast North Island) and L (off shore north-east Northland) (Fig. 12). It is likely that the small fish were part of a common stock which arrived off the New Zealand coast from the north-east. Length-frequency distributions from area L show that at least some of the small fish passed through that off-shore area on the way to New Zealand in January.

Few catches were sampled in the Bay of Plenty (area D), and none between East Cape and Hawke Bay (area E) because most of the fishing in those areas was by the small seiners. Ministry of Agriculture and Fisheries observers were denied access to those vessels for most of the season. Such gaps in the information on the skipjack resource make it difficult to gain a full understanding of the resource while it is in New Zealand.

The estimated numbers of fish of different lengths in the 1979 catches are presented in Table 13. These estimates were obtained by converting the number of fish of each length to weight of fish at each length by use of a previously determined length-weight relationship (see below). These weights were scaled up by the weights of the catches to yield total weights of fish at each length, which were then converted back to total numbers at each length.

Length-weight relationship

A relationship was not calculated for 1979. However, it would probably have been similar to that derived for 1977 (see Fig. 6 and Table 4 *in* Habib 1978a).

Age and growth

Unlike the growth rates observed in 1976 (Vooren 1976), growth as indicated by the movements of modal

TABLE 13: Estimated number of skipjack of different lengths in the 1979 purse-seine catch in New Zealand

Length (cm)	Est. No. in season's catch	% of est. total No.	Length (cm)	Est. No. in season's catch	% of est. total No.
34	310	—*	52	97 291	2.2
35	226	—	53	90 083	2.1
36	7 656	0.2	54	96 415	2.2
37	14 235	0.3	55	85 708	2.0
38	10 326	0.2	56	58 913	1.4
39	11 960	0.3	57	46 394	1.1
40	33 603	0.8	58	32 344	0.7
41	57 470	1.3	59	11 472	0.3
42	118 567	2.7	60	8 248	0.2
43	251 765	5.8	61	5 251	0.1
44	640 974	14.8	62	4 976	0.1
45	837 524	19.3	63	1 641	—
46	760 027	17.5	64	485	—
47	456 402	10.5	65	406	—
48	269 318	6.2	66	269	—
49	127 179	2.9	67	0	0
50	114 534	2.6	68	27	—
51	80 950	1.9	Total	4 332 950	

* Less than 0.1% of total.

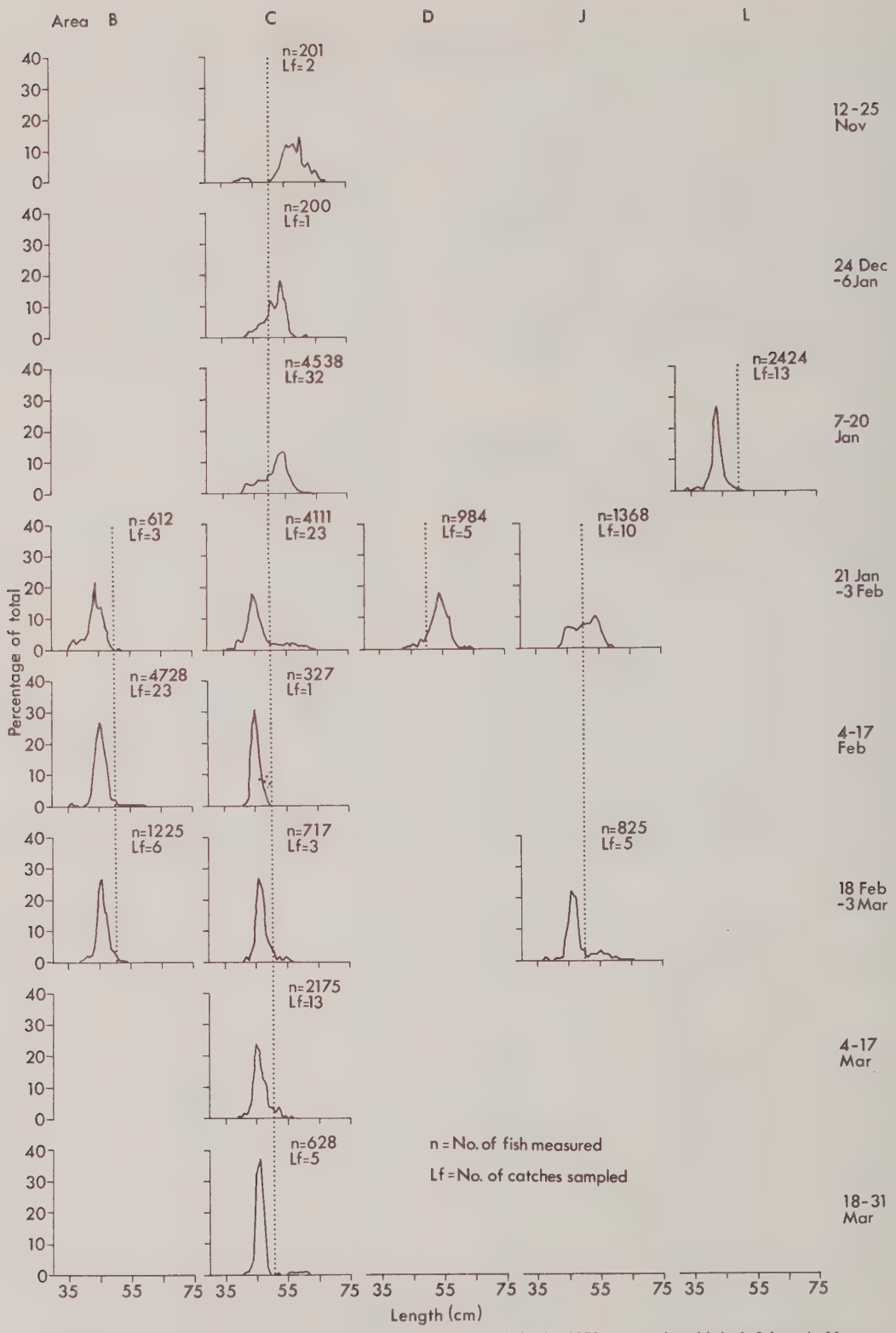


Fig. 12: Length-frequency distributions by area by 2-week intervals in the 1979 purse-seine skipjack fishery in New Zealand.

size classes of fish was not apparent in 1979. Based on growth curves figured by Vooren (1976) and the length composition of 1979 catches, the possible age range of skipjack in 1979 was 13 to 38 months, with most fish being 18 to 21 months.

Further information on age and growth of New Zealand skipjack will become available when the South Pacific Commission analyses the tagging data collected during the *Hatsutori Maru* cruise in New Zealand waters last summer.

Food and feeding

Stomach contents were investigated in 386 skipjack (172 females, 214 males) during the season. Samples came from all areas in the fishery and were collected at various times during the day. Almost three-quarters of the stomachs were empty. Those with food contained exclusively the planktonic euphausiid *Nyctiphanes australis*.

Few fish contained much food. Some 83% of stomachs were less than one-quarter full, 14% between a quarter and half full, and 3% over half full.

An interesting observation was that the fish sampled in area L (off shore north-east Northland, Fig. 1) were all empty, and on examination their stomachs were found to be strongly contracted as if the fish had not eaten for some days. Stomachs similarly contracted have been observed during other seasons in samples from bodies of fish which had obviously only recently arrived in New Zealand waters (data in MAF files). We believe that the skipjack which visit New Zealand travel quickly from the tropical areas to the north and eat little, if anything, along the way. Justification for such a long and taxing journey is presumably the substantial concentrations of the food organism *Nyctiphanes australis* in New Zealand waters.

Gonad condition

Gonads were examined in the fish dissected for stomach analyses. All gonads were undeveloped. As most skipjack in the catches were close to 45 cm (see Table 13), the length at which this species usually undergoes first spawning (Brock 1954, Yoshida 1964), it is likely that most fish had not yet spawned, but would spawn in other parts of their range.

Population identification

In earlier seasons large blood samples have been collected from the purse-seine catches for genetic studies on skipjack population identification. This was discontinued in 1979. However, samples were collected on *Hatsutori Maru* (see Kearney and Hallier 1979). Results of analyses of those samples will be available in later South Pacific Commission publications.

Migrations

Results from tagging undertaken on the research vessel *Hatsutori Maru* (see South Pacific Commission's interim reports listed in Kearney and Gillett 1978, Kearney pers. comms.) have established that New Zealand shares at least part of its skipjack resource with the island nations to the north. Some fish which were tagged near Fiji and Wallis and Futuna Islands (see map *in* Kearney 1978a) were recaptured in New Zealand; and one skipjack which was tagged near Poor Knights Islands was recovered recently near Fiji (Table 14). In addition, some skipjack which were tagged near Fiji, Wallis, and Futuna have also been recovered in French Polynesia, Samoa, Tonga, Tuvalu, Gilbert Islands, Solomon Islands, and in the Trust Territory of the Pacific Islands (Kearney pers. comm.). Thus, there appears to be a sharing – directly or indirectly – of skipjack between New Zealand and some, if not all, of the above nations.

Skipjack fisheries of these nations are rapidly developing (Uchida 1975). If there is to be optimum international use of this shared skipjack resource, there is a need for an international body to manage the resource, possibly a regional fisheries body of the kind suggested by Kearney (1976). New Zealand would need to seriously consider being a signatory to such a body.

TABLE 14: International data for skipjack released or recaptured in New Zealand waters during the 1979 skipjack season (data from Kearney 1978b, Kearney and Hallier 1978, 1979, and Kearney pers. comm.)

Release data					Recapture data				
Date	No. tagged	Position	Country	Fish length (cm)	Date	Position	Country	Fish length (cm)	Distance travelled (km)
9.2.78	251	18°53′ S, 179°16′ E	Fiji	45.0	5. 3.79	35°48′ S, 175°27′ E	New Zealand	55.5	1 912
6.4.78	1 642	16°56′ S, 179°24′ W	Fiji	50.4	21.11.78	36°00′ S, 176°00′ E	New Zealand	58.5	2 173
6.4.78	1 642	16°56′ S, 179°24′ W	Fiji	51.0	19. 1.79	35°53′ S, 175°52′ E	New Zealand	58.5	2 160
17.5.78	1 054	13°29′ S, 176°07′ W	Wallis	53.0	7. 3.79* to 22. 3.79	35°49′ S, 175°18′ E to 36°04′ S, 175°55′ E	New Zealand	?†	2 626 to 2 641
18.5.78	1 035	13°31′ S, 176°05′ W	Wallis	54.0	15. 1.79 to 25. 1.79	35°37′ S, 175°16′ E to 36°00′ S, 176°02′ E	New Zealand	54.1	2 630 to 2 641
19.5.78	1 982	13°30′ S, 176°05′ W	Wallis	49.0	4. 3.79	35°30′ S, 175°01′ E	New Zealand	54.0	2 605
20.5.78	2 910	13°17′ S, 176°23′ W	Wallis	48.0	5. 3.79 to 6. 3.79	35°52′ S, 175°54′ E to 36°02′ S, 176°07′ E	New Zealand	51.5	2 628 to 2 648
20.5.78	2 910	13°15′ S, 176°20′ W	Wallis	50.5	5. 3.79 to 6. 3.79	35°52′ S, 175°54′ E to 36°02′ S, 176°07′ E	New Zealand	56.0	2 628 to 2 648
20.5.78	2 910	13°17′ S, 176°16′ W	Wallis	52.0	?	?	New Zealand	?	?
29.5.78	486	14°05′ S, 177°58′ W	Futuna	51.0	23. 3.79	36°03′ S, 175°20′ E	New Zealand	56.0	2 542
14.6.78	1 637	13°42′ S, 171°45′ W	Western Samoa	52.0	?	?	New Zealand	?	?
2.3.79	3 692	35°24′ S, 174°54′ E	New Zealand	46.0	17. 6.79	15°56′ S, 179°41′ E	Fiji	51.4	2 220

* Where ranges of dates, positions, and distances are given, exact data are not available.
† No data.

References

BARKLEY, R.A., NEILL, W.H., and GOODING, R.M. 1978: Skipjack tuna, *Katsuwonus pelamis*, habitat based on temperature and oxygen requirements. *Fishery Bulletin (NOAA) 76*: 653–62.

BELL, G.R. 1976: Aerial spotting for pelagic fishes. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 47–8. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

BROCK, V.E. 1954: Some aspects of the biology of the aku, *Katsuwonus pelamis*, in the Hawaiian Islands. *Pacific Science 8*: 94–104.

CLEMENT, I.T. (George). 1976: Distribution and abundance of skipjack, 1975–76. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 36–9. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

———1978: School fish sightings around New Zealand, 1976-77. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 35–42. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

EGGLESTON, D. 1976: The *Paramount* project: a purse seine survey of New Zealand's skipjack resource. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 31–5. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

EGGLESTON, D., and PAUL, L.J. 1978: Satellites, sea temperatures, and skipjack. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 75–84. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

HABIB, G. 1976: The 1975–76 purse seine skipjack fishery. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 40–6. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

———1978a: Skipjack biology and the 1976–77 purse-seine fishery. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 17–26. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

———(Comp.) 1978b: Supplement on N.Z. 1977–78 tuna season. *Catch '78, August Supplement*. 24 pp.

HABIB, G., CLEMENT, I.T., and FISHER, K.A. (in press): The 1977–78 purse-seine skipjack fishery in New Zealand waters. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 25.*

HINDS, V.T. 1974: Purse seining. *Catch '74 1 (4)*: 5–16.

KEARNEY, R.E. 1976: A regional approach to fisheries management in the South Pacific Commission area. Paper presented to the South Pacific Forum Meeting on the Law of the Sea, Suva, 13 and 14 October, 1976. South Pacific Commission, Noumea, New Caledonia. 19 pp.

———1978a: Skipjack survey and assessment programme annual report for the year ending 31 December 1977. South Pacific Commission, Noumea, New Caledonia. 28 pp.

———1978b: Interim report of the activities of the skipjack survey and assessment programme in the waters of Fiji (26 January - 18 February, 28 March - 10 April 1978). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 5.* 17 pp.

KEARNEY, R.E., and GILLETT, R.D. 1978: Interim report of the activities of the skipjack survey and assessment programme in the waters of the Gilbert Islands (5–25 July 1978). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 11.* 13 pp.

KEARNEY, R.E., and HALLIER, J-P. 1978: Interim report of the activities of the skipjack survey and assessment programme in the waters of Wallis and Futuna Islands (4–31 May 1978). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 7.* 13 pp.

———1979: Interim report of the activities of the skipjack survey and assessment programme in the waters of New Zealand (17 February - 27 March 1979). *Skipjack Survey and Assessment Programme Preliminary Country Report, South Pacific Commission, Noumea, New Caledonia, No. 16.* 20 pp.

MARR, J.C. 1951: On the use of the terms abundance, availability and apparent abundance in fishery biology. *Copeia 1951*: 163–9.

ORANGE, C.J. 1961: Spawning of yellowfin tuna and skipjack in the eastern tropical Pacific, as inferred from studies of gonad development. *Bulletin of the Inter-American Tropical Tuna Commission 5*: 459–502.

RAJU, G. 1964: Studies on the spawning of the oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in Minicoy waters. *In* Proceedings of the Symposium on Scombroid Fishes held at Mandapam Camp from January 12–15, 1962, pp. 744–68. Marine Biological Association of India, Mandapam Camp, Southern India.

RICHARDSON, B.J. 1978: Skipjack tuna stock identification. *In* Habib, G., and Roberts, P.E. (Comps.), Proceedings of the Pelagic Fisheries Conference, July 1977, pp. 63–4. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 15.*

ROBERTSON, D.A. 1975: Aerial survey of pelagic fish. *Catch '75 2 (6)*: 3–4.

SQUIRE, J.L. 1972: Apparent abundance of some pelagic marine fishes off the southern and central California coast as surveyed by an airborne monitoring program. *Fishery Bulletin (NOAA) 70*: 1005–19.

UCHIDA, R.N. 1975: Recent development in fisheries for skipjack tuna, *Katsuwonus pelamis*, in the central and western Pacific and the Indian Ocean. *FAO Fisheries Technical Paper, No. 144*: 1–57.

VOOREN, C.M. 1976: Biological data on skipjack in New Zealand waters, 1973–76. *In* Proceedings of the Skipjack Tuna Conference, July 1976, pp. 12–6. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 11.*

YOSHIDA, H.O. 1964: Skipjack tuna spawning in the Marquesas Islands and Tuamotu Archipelago. *U.S. Fish and Wildlife Service Fishery Bulletin 65*: 479–88.